Confirmatory Factor Analysis Test of an Hierarchical Model of Health Behaviors

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SUMMARY

Appropriate measures of health behavior patterns are required to accurately identify factors influencing those patterns. Precise knowledge of these influential factors can be important in programs to improve health practices as a means of maintaining or enhancing personnel readiness. The importance of such programs to the U.S. Navy is indicated by the existence of the multifaceted Health and Physical Readiness Program, which includes a number of components concerned with the modification of lifestyle patterns.

The present study extended prior work which suggested that a broad range of activities falling under the general rubric of "health behaviors" could be divided into two large first-order subsets of correlated behaviors and that each of the first-order subsets could be divided into two second-order subsets of behaviors that were especially strongly correlated. From a measurement perspective, the first-order subsets of behaviors could be regarded as indicators of individual differences on two general dimensions of health behavior, which were labelled preventive health practices and risk taking behaviors. The second-order subsets of behaviors within preventive health practices could be regarded as indicators of individual differences on dimensions of wellness promoting behavior, indexed by behaviors such as watching one's weight and eating the right foods, and accident control behavior, indexed by behaviors such as checking hazards around the home and maintaining current knowledge of first aid practices. The second-order subsets of risk taking behaviors could be regarded as indicators of individual differences on dimensions of avoidance of hazardous substances, indexed by behaviors such as not consuming alcohol or tobacco, and of taking risks as a pedestrian and/or driver, indexed by behaviors such as following traffic rules and not driving fast. The proposed health behavior sets were partially overlapping, as evidenced by correlations between scores on the hazard avoidance dimension and the two preventive health practices dimensions.

The present study examined the health behavior patterns of 103 U.S. Navy recruits and 213 U.S. Navy shipboard personnel to address two issues. First, is it possible to develop a single measurement model that applies generally to Navy personnel? If not, there would be problems for program evaluations or other efforts that require measurement of health behavior. Second, should a 2-dimensional or a 4-dimensional model be adopted to assess differences in

health behaviors? Answers to these questions can influence the precision of estimates of the effects of programs and the health and performance consequences of health behavior patterns.

Confirmatory factor analyses of covariance matrices demonstrated that:

(a) A single measurement model was appropriate for the different groups being compared.

(b) Dimensions representing each of the four second-order health behavior subcategories were required to fully represent the range of distinct health behavior dimensions.

The analyses also showed that several behaviors which had marginal factor loadings in prior work could be regarded as reliable indicators of the behavioral dimensions. In the case of substance use risk, the additional indicators suggested that the concept should be broadened to encompass a general tendency to avoid exposure to substances or conditions which might impair health (e.g., pollution, germs).

The present results combined with our prior findings provide a measurement framework for evaluating health behavior in Navy populations. This measurement model will permit researchers to test hypotheses regarding programs oriented toward improving health behavior more effectively.

Health habits are an important part of a person's lifestyle because of their influence on health and well-being. Previous studies of the patterning of health behaviors in U.S. Navy populations have demonstrated replicable dimensions of behavior (Vickers, Conway & Hervig, 1988; Vickers & Hervig, 1984). Identifying reliable patterns of health behaviors permits individual differences to be assessed as differences in location on dimensions of health behavior. This achievement is important because the individual differences thus measured reflect integrated lifestyles which may be stronger determinants of health and well-being than isolated individual behaviors (Belloc, 1973; Metzner, Carman & House, 1983). The assertion that integrated lifestyle measures are better predictors of health and well-being than individual health behaviors is an hypothesis which can be tested most effectively with well-developed, psychometrically sound measures of the lifestyle patterns pertinent to health.

This paper reports the results of a study which replicated and extended the prior findings of Vickers, et al. (1988) by applying confirmatory factor analysis to the problem of measuring health behaviors. This extension was undertaken because the prior studies which demonstrated reliable health behavior dimensions utilized exploratory factor analysis procedures which may have capitalized on associations unique to the samples being studied. The empirical foundation for evaluating health-relevant lifestyles would be stronger if the original findings could be confirmed in additional samples. Based on prior findings, the confirmatory analyses conducted in this study were designed to address three issues. First, how many dimensions must be considered to adequately represent health behaviors? Second, how highly correlated are the different dimensions of health behavior? Third, how stable are the results pertaining to these first two questions when compared across two different samples?

An hierarchical model of health behaviors suggested in prior work provided the primary point of departure for addressing the above questions. With regard to the number of dimensions required to represent health-relevant lifestyles, Vickers, Conway, and Hervig (1988) found that 2- and 4-factor representations of health behavior merited consideration, as each produced stable factors across two large samples of Navy personnel. With regard to the correlations between lifestyle dimensions, the earlier work indicated modest correlations in the range of .20 to .40. Based on the pattern of these correlations, an hierarchical organization was suggested to summarize the relationships between the 2- and 4-factor representations. The 2-factor representation contrasted preventive health behaviors and risk-taking behaviors. The 4-factor representation distinguished between wellness maintenance behaviors, accident prevention behaviors, risk-taking relative to driving and pedestrian behavior, and risk-taking in the form of substance consumption. The actions which were indicators of individual differences in wellness behavior and accident prevention in the 4-factor solution included most behaviors which defined a preventive health behavior dimension in the 2-factor solution. Similarly, behaviors defining the traffic risk-taking and substance risk-taking dimensions in the 4-factor solution were basically the same behaviors that defined a general dimension of risk-taking in the 2-factor solution. When unit-weighted item composites were computed to represent the wellness and accident prevention dimensions, the resulting scales were moderately positively correlated, as were the two risk-taking composites. Thus, in each case, there was reason to believe the items defining each factor in the 2-factor solution could be subdivided into subsets of behaviors that consistently were more strongly related within subsets than across subsets, but still generally positively related. The separation between the two general domains was not perfect, however, as substance use risk-taking also tended to be negatively correlated with wellness and accident prevention behaviors. Based on these considerations, the hierarchical structure for health behavior dimensions shown in Figure 1 was proposed by Vickers, et al. (1988). One prediction in the present study was that the associations underlying this hierarchical model would replicate, including both the need for 4 dimensions to represent health behaviors and the patterning of associations between those behaviors.

The previous study also provided a basis for asserting that the factor structures and correlations outlined above were comparable in a recruit sample and a sample of U.S. Navy shipboard personnel. This position was supported by direct comparison of the factor structures through a number of statistical techniques (e.g., computation of coefficients of congruence) and by direct inspection of the correlations between unit-weighted item composites. Direct statistical tests of the comparability of the results in the two samples were not provided by the prior analyses, however. One objective of the present study, therefore, was to provide more formal assessments of sample-to-sample stability of the patterning of associations between individual behaviors and between health behavior dimensions. Based on the prior study, it was predicted that a single model would fit the data from both groups.

To summarize the preceding points, three predictions were tested in this study. First, a 4-dimensional representation of health behaviors would fit the data significantly better than a 2-dimensional model. Second, the pattern of interdimensional correlations noted in previous samples would be obtained in additional samples. Third, the two groups of U.S. Navy personnel being studied would produce comparable factor structures and comparable correlations between the health behavior dimensions.

The application of confirmatory factor analysis to address the preceding questions and hypotheses extended prior findings in two important ways. The first was the replication of prior findings in an additional sample of men. The second was a test of the sensitivity of the results to the choice of statistical methods for analyzing the data. While the analyses could have employed procedures identical to those in the prior study, this approach might have produced replication that was determined largely by the specific methods of analysis and the associated criteria for choosing between alternative models. The potential influence of these methodological choices on the replication attempts in this study was minimized by shifting from exploratory principal components analyses of correlations to confirmatory factor analysis of covariance matrices. Exploratory procedures were necessary in the earlier work because there were only general guidelines in the previous literature regarding how many dimensions to expect and which sets of behaviors would define the dimensions. The shift to confirmatory analysis in this study was possible because the earlier work highlighted two competing measurement models and specified which behaviors were reasonable indicators for each dimension in each model. Without this information, the confirmatory analysis procedures could not be effectively employed.

The shift to confirmatory factor analysis in this study provided several opportunities to refine the prior findings. This shift permitted direct comparison of the competing 2- and 4-factor representations of health behavior in terms of their ability to reproduce the data from two new samples using a formal statistical test of how well each model reproduced the data. The shift permitted comparison of the previously reported correlations between the hypothesized dimensions, which were estimated by correlating unit-weighted sums of responses to items loading on each dimension, to estimated correlations between latent traits with adjustment for measurement error to approximate correlations between true scores. One effect of the shift in analysis strategy, therefore, was expected to be stronger estimated associations between dimensions, as previously reported correlations could be expected to underestimate true correlations between the behavioral dimensions because of measurement error. The extent of this underestimation could differ for different measures, a point which was noted previously in a suggestion that modest correlations between substance-use risk-taking and the other dimensions might be a product of the low reliability of this brief scale (Vickers, et al., 1988). Finally, the confirmatory analysis employed a simplified measurement model for the health behavior dimensions relative to the exploratory analysis. The simplification was achieved by fixing some factor loadings at zero, thereby incorporating the criterion of simple structure into the analysis more forcefully than is the case in exploratory analysis. Simple structure occurs when each item has a substantial loading on one factor and zero loadings on all other factors.

Overall, the present study attempted to replicate prior findings and, at the same time, to shift from exploratory comparisons of alternative factor structures, a choice necessitated by limited knowledge available at the time of the prior study, to confirmatory analyses which provide additional statistical evaluations of factor similarity across samples. The changes provided the potential to obtain a simplified, parsimonious model of health behaviors that could be applied to other populations and samples. The confirmatory factor analyses reported below compared the structure of health behaviors in two distinct groups of U.S. Navy personnel to evaluate the generality of the factor structure. The generality of factor solutions was a concern, because a generally applicable structure for health behaviors can be developed only if a reasonably well-defined measurement model exists which can be applied with reasonable confidence to different groups. For a variety of reasons, achieving this level of measurement can be difficult in the social sciences (Blalock, 1982), so confirmation of between-group stability is desirable whenever a measurement model is proposed for some psychological or behavioral construct(s). In the prior analyses, some health behaviors produced large, consistent relationships to the underlying dimensions in each of two large samples, but other behaviors produced more variable associations across the two samples. The present application of maximum likelihood confirmatory factor analysis procedures in two new samples of Navy personnel provided an opportunity to further evaluate the marginal factor markers from the prior studies with specific significance tests for their hypothesized factor loadings.

METHOD

Sample

Defining two terms used to classify respondents in the presentation of results will help clarify subsequent discussion. The term "groups" will refer to a distinction between U.S. Navy recruits and U.S. Navy shipboard personnel. These groups will be referred to as the "recruit" and "shipboard" groups. The term "sample" will refer to a distinction between individuals who provided data analyzed for the first time in the confirmatory factor analyses reported below and individuals who provided data used in earlier exploratory factor analyses. These samples will be referred to as the "confirmatory" and "exploratory" samples.

Combining the two distinctions outlined above, data from four distinct sets of respondents are referred to in this report:

(a) Exploratory Shipboard personnel were 812 male U.S. Navy shipboard personnel who averaged 25.9 (S.D. = 6.0, range = 18-50) years of age, and nearly all of these participants had 12 years (68.4%) or more (25.4%) of formal schooling. The ethnic composition of this sample was 79% Caucasian, 9% Black, 6% Malayan/Filipino, and 5% Hispanic. Enlisted personnel comprised 93% of the sample and officers 7%.

(b) Confirmatory Shipboard personnel were 213 male U.S. Navy personnel assigned to shipboard duty. The men averaged 26.5 (S.D. = 6.5; range = 18-51) years of age, and nearly all had 12 years (66.1%) or more (29.1%) of formal schooling. The ethnic composition was 83% Caucasian, 6% Black, 5% Malayan/Filipino, and 3% Hispanic. Enlisted personnel comprised 87% of the sample and officers 13%.

(c) Exploratory Recruit personnel were 605 recruits entering U.S. Navy basic training. The typical recruit was 18.8 (S.D. = 2.3, range = 16-35) years of age and had a high school diploma (82%) or Graduate Equivalency Diploma (4%). The primary ethnic groups were 67% Caucasian (67%), Blacks (19%), and Hispanics (8%).

(d) Confirmatory Recruit personnel were 103 male U.S. Navy recruits. The typical recruit in this sample was 19.3 (S.D. = 2.7, range = 17-32) years of age and had a high school diploma (96%) or Graduate Equivalency Diploma (1%). The primary ethnic groups were Caucasians (75%), Blacks (14%), and Hispanics (6%).

Instrument

A 40-item health behavior questionnaire was completed (Appendix A). Respondents indicated how well each item described their typical behavior using response options ranging from "Strongly Disagree" (scored 1) to "Strongly Agree" (scored 5) for recruits, or as a description of how characteristic the behavior was of the person from "Not at all like me" (scored 1) to "Very much like me" (scored 5) for shipboard personnel.

Analysis Procedures

Confirmatory factor analyses were conducted with LISREL VI (Joreskog & Sorbom, 1981).

Two- and four-dimensional models were compared by fixing the loading for a given health behavior item at zero for any hypothesized dimension for which the average loading for that item was less than .25 in the previous exploratory principle components analyses reported by Vickers, et al. (1988). The resulting measurement models for the 2- and 4-dimensional confirmatory factor analyses are shown in Appendix A.

Relative to the frequently used standard of a loading of .30 or greater to select items defining a dimension, the criterion used here was lenient. This leniency was considered acceptable, because a tendency toward over inclusiveness permitted a test of the consistency and significance of loadings for previously marginal items in analyses using a different analytic model.

The reference point used to establish the scaling of the measurement model was established by fixing the variance of the latent traits at 1.00. This method of constraining the item factor loadings permitted loadings to be estimated for each item in each solution, thereby making it possible to test for the significance of each hypothesized factor loading. All latent traits were assumed to be correlated, so each possible pairwise correlation was included in each model and estimated for each solution.

Multiple group analyses were conducted for the 2- and 4-factor models following procedures outlined by Joreskog and Sorbom (1981, pp. V.5-V.13). First, the measurement model and the correlations between dimensions were constrained to be equal for recruits and shipboard personnel. Second, the same structural model was applied to both groups, but the parameters were estimated separately for each group. The difference between the chi-squares for the first and second models provided a statistical test of the hypothesis that the same structural model applied to both samples. For convenience in discussing the findings from the analyses, the results obtained in the first of these analyses will be referred to as the "group-invariant model" solution, and the results of the second of these analyses will be referred to as the "group-specific model" solution.

The multiple group confirmatory factor analysis procedures were applied to the exploratory samples primarily to obtain parameter estimates with moderately large groups which could be cross-validated in the confirmatory sample. The exploratory sample did not provide a strong test of hypotheses regarding alternative models because the models were based on prior exploratory analyses of the data from these two sets of subjects. However, the application of confirmatory factor analysis to the exploratory data did provide several useful extensions of the prior analyses. First, direct statistical tests of the equivalence of factor structures across groups was provided. Second, the effects of choice of analysis procedure could be examined by comparing the present maximum likelihood analysis of covariance structures with correlated dimensions to the results of the previous principle components analysis with orthogonal dimensions. Third, the effect of simplifying the factor structure by fixing small (i.e. $< .25$) factor loadings at zero could be assessed. Finally, estimates of true score correlations between latent traits were obtained which could be compared to the correlations obtained with unit-weighted sums of item responses as a means of estimating the intercorrelations. Thus, the confirmatory factor analysis of the exploratory data complemented prior analyses as well as providing a basis for a strong test of the reliability of factor structures across groups. The results of fitting the confirmatory factor analysis models to these data, therefore, are reported in parallel with those for the confirmatory sample with the understanding that the findings must be interpreted cautiously.

The structural model parameter estimates from the confirmatory factor analyses of the exploratory sample data were applied to the data from the confirmatory sample to cross-validate them. The cross-validation was accomplished by specifying a model that fixed each parameter value, including item loadings for the measurement model and the estimated correlations between latent traits, at the values estimated in the exploratory sample data. This completely constrained model then was applied to the data from the confirmatory sample. The third step in the cross-validation procedure assumed that the same pattern of factor loadings and correlations applied in the confirmatory sample data, but that the optimum values for the estimated values of these loadings and correlations differed from those derived from the exploratory sample data. To evaluate this possibility, the same structural model was assumed, but the values for the parameters comprising the model were estimated from the confirmatory sample data. The difference between the chi-square value for the completely constrained model and the model which assumed sample-specific parameter estimates provided a statistical test of the hypothesis that the overall structural model was invariant across samples.

Guidelines for evaluating the goodness-of-fit of structural equation models are not completely agreed upon at this time (Marsh, Balla & McDonald, 1988; Mulaik, et al., 1989), so five different indicators were used to evaluate the alternative health behavior models. Each index involved slightly different assumptions about what indicates good fit of a model to data, so any model which was better than competing models by all of these criteria would be preferred under a variety of assumptions. The computational formulae for these indices are described in Marsh, et al. (1988), Mulaik, et al. (1989) and the sources cited below, and they will not be repeated here. Instead, general definitions of the indices and their associated assumptions are given. The indices included:

(a) The root mean square (RMS) for a model is the square root of the average squared difference between the covariances estimated from the model and the observed sample covariances. Conceptually, this measure of fit is akin to the standard deviation or standard error in other types of analyses. All other things equal, a model with a smaller RMS is preferable to alternative models.

(b) Hoelter's (1983) "critical N" is the largest sample size for which the observed goodness-of-fit of the model would produce a statistically nonsignificant chi-square value. The chi-squares reported in LISREL models are the product of a fitting function value and the sample size (Bollen, 1989), so a large chi-square can be obtained because the model poorly reproduces the observed covariance matrix or because the sample size is very large. Hoelter (1983) argued that the fit of a model to data can be accepted as adequate provided observed fit would not be statistically significant for a "large" sample and recommended a critical N of 200 times the number of groups being compared as a reasonable definition of a "large" sample.

(c) Bentler and Bonnet's (1980) index is a measure of fit akin to the proportion of variance explained in regression or analysis of variance models. In this study, the index was computed by fixing all factor loadings at zero to define a null model and assuming perfect reproduction of the covariance matrix as a saturated model. The Bentler-Bonnet index (BBI) for each model tested was computed by dividing the chi-square for that model by the chi-square for the null model and subtracting this ratio from one.

(d) Tucker and Lewis' (1973) fit index estimates the proportion of non-chance covariance explained by the model. The null model for these computations was the same as for the BBI, but the Tucker-Lewis index (TLI) takes into account the chi-square expected given chance variation in the estimated covariances. This value is 1.00, so the minimum chi-square for a given model is equal to the degrees of freedom for that model. The non-chance covariance represents the portion of the data which is to be explained by a model and is equal to the observed covariance minus that expected by chance. The TLI is the proportional reduction in the nonchance variance and will be greater than the BBI unless the model has an average reduction in the chi-square of less than 1.00.

(e) Parsimony indices were computed for the BBI and TLI following procedures outlined by Mulaik, et al. (1989) because other goodness-of-fit indices tend to produce larger values any time parameters are added to a model. For example, the addition of a dimensional loading or a correlation between factors will reduce the chi-square in any case in which the added parameter is not exactly zero. Measures such as the BBI, therefore, necessarily will indicate better fit for more complex models. However, it is a general scientific principle that, all other things equal, simpler models should be preferred to more complex models. In addition, Bentler and Mooijaart (1989) have demonstrated that parsimonious models have smaller sampling variances for model parameters. Mulaik, et al. (1989) recommend that the complexity be represented by the proportion of the original degrees of freedom in the data used by the model. Parsimony indices can be computed from other fit indices by multiplying each of them by this proportion.

In the present application of confirmatory factor analysis, the goodness-of-fit indices generally produced small to moderate values relative to recommended fit criteria in the literature. However, in the present application, the absolute value of the fit indices is less important than the relative values for the models being compared. This assertion applies, because the intent is to choose between pre-determined alternative models which are the most plausible possibilities for summarizing reliable, replicable covariations between health behaviors. In addition, the parsimony indices showed little shrinkage from the raw fit indices, because these models employ relatively few degrees of freedom.

RESULTS

Replicability of Structural Estimates Between Groups

The first research question addressed was whether the two groups sampled (i.e., shipboard personnel and recruits) produced comparable structural equations. The chi-square comparisons for the group-invariant and group-specific models were statistically significant in 3 of 4 tests (Table 1). Also, as expected when more complex models are fitted to data, the BBI increased and the RMS decreased for the group-specific models. Despite these findings, the group-invariant model was preferable to the group-specific model by several criteria. The significant chi-square differences for the exploratory sample were largely the product of sample size as indicated by the large critical Ns for the invariance comparisons in these samples. When the exploratory sample model was cross-validated in the confirmatory sample, the group-specific model actually provided a worse fit to the data. Finally, the modest improvements in fit were not justified by the increases in model complexity required to achieve those gains. The critical N and TLI indices both were larger for 5 of 6 comparisons. All but one parsimony index value was higher for the group-invariant model, and the one remaining parsimony index was identical for the two models.

Comparison of 2- and 4-factor Models

The second research question addressed was whether 2 or 4 dimensions were appropriate to represent health behaviors. In every comparison made, the 4-dimensional model produced a statistically significant decrease in the chi-square and was superior according to every fit index (Table 1). Also, the absolute magnitude of the differences actually was larger for the parsimony indices.

Table 1

Goodness-of-fit Summary for Confirmatory Factor Analyses

		Exploratory Sample			Confirmatory Sample			Cross-Validation		
	df	Chi-square	RMS	Critical N	Chi-square	RMS	Critical N	Chi-square	RMS	Critical N
Model										
2-Dim. Invariant (2I)	1511	5285.16	.142	794	2657.25	.146	352	2732.56*	.155	353
2-Dim. Specific (2S)	1462	5164.67	.130	786	2593.48	.142	349	2738.01*	.161	352
4-Dim. Invariant (4I)	1496	4507.01	.123	921	2400.32	.122	386	2511.66*	.137	384
4-Dim. Specific (4S)	1432	4300.15	.106	924	2313.63	.119	383	2568.08*	.153	376
Chi-Square Differences: Invariance Comparison										
2I vs. 2S	49	120.49		825	63.77		287	-5.45#		#
4I vs. 4S	64	206.86		602	86.69		320	-56.42#		#
Dimensional Comparison										
2I vs. 4I	15	778.26		50	256.93		33	220.90#		#
2S vs. 4S	30	864.52		77	279.85		53	169.93#		#

Goodness-of-Fit	Exploratory Sample				Confirmatory Sample				Cross-Validation			
Indices	BBI	TLI	Pars 1	Pars 2	BBI	TLI	Pars 1	Pars 2	BBI	TLI	Pars 1	Pars 2
2I	.623	.687	.603	.665	.431	.579	.417	.561	.375	.583	.375	.583
2S	.632	.683	.592	.640	.445	.571	.417	.526	.374	.581	.374	.581
4I	.679	.748	.651	.717	.486	.665	.466	.638	.426	.662	.426	.662
4S	.693	.749	.636	.688	.505	.659	.464	.605	.413	.642	.413	.642

NOTE: "RMS" refers to the root mean square for the residuals. "BBI" indicates the Bentler-Bonnet index. "TLI" indicates the Tucker-Lewis index. "Pars 1" and "Pars 2" indicate the Mulaik, et al. (1989) parsimony indices for the BBI and TLI, respectively.

* There were 1560 degrees of freedom for the cross-validation models, because all parameters were fixed.

There were zero degrees of freedom for these chi-squares as both models being compared had 1560 degrees of freedom.

Measurement Model Parameter Estimates

The preceding analyses indicated that a 4-dimensional group-invariant model was appropriate. The measurement model parameter estimates for this overall model were examined to address three secondary research issues before examining the correlations between behavior dimensions. One issue was an assessment of how much the choice of principle components analysis in the prior exploratory analyses had affected conclusions regarding the appropriate indicators for each dimension. The second issue was whether the use of a lenient criterion to identify behaviors defining a dimension had resulted in the inclusion of any trivial associations. If so, a simplified measurement structure would be possible. The third issue was whether any important indicators of the different dimensions had been excluded from the model.

The shift from exploratory principle components analysis with orthogonal factors to confirmatory maximum likelihood analysis with correlated factors did not substantially modify the structural model. In Table 2, the health behavior items have been grouped according to the factor on which they had the highest loading in the prior analyses. Within each group, the behaviors have been ordered according to the size of their loading on that factor in the exploratory analyses. Thus, if the prior results were perfectly replicated, each health behavior item would have its largest loading on the dimension defined by its group, and the loadings would decrease from the top to the bottom of the list within each category.

The results in Table 2 for the exploratory sample are directly pertinent to estimating the effects of the choice of analysis procedures. The choice had very limited effects. The rank order of factor loadings was broadly consistent with the prior results, and the primary factor loading for nearly all items was the same as that in the earlier principle components analyses. However, the items which dealt with avoiding germs, and getting inoculations would have shifted to a different factor if the maximum likelihood procedure had been used. Overall, only 2 of the 58 hypothesized loadings, those for "Fix broken things" and "Know first aid" on Wellness Behavior, were less than twice their estimated standard errors. Both items had an average loading of .25 in the prior exploratory principle components analyses, thereby barely meeting the lenient criterion for inclusion in the present measurement model. Thus, the shift from exploratory principle components analysis of the interitem correlation matrix to confirmatory factor analysis of the interitem

Table 2
Maximum Likelihood Measurement Model Parameter Estimates

	Sample:							
	E	C	E	C	E	C	E	C
Accident Control								
Emergency Numbers	.746	.732						
Destroy Medicines	.735	.750						
First Aid Kit	.728	.748						
Check Hazards	.779	.678						
Fix Broken	.539	.401	$\underline{.060}$	$\underline{.077}$				
Know First Aid	.486	.426	$\underline{.082}$	$\underline{.017}$				
Watch Health Signs	.472	.238	.422	.509				
Relax	.381	.348						
Get Enough Sleep	.350	.463						
Wellness Behavior								
Dental Checkup			.704	.741				
Food Supplements			.553	.606				
Take Vitamins			.624	.677				
MD Checkup	.260	.367	.561	.466				
Exercise			.699	.684			.101	.176
Discuss Health			.675	.473				
Health Information			.764	.593				
Floss			.572	.603				
Limit Foods			.552	.504			.185	.387
Watch Weight			.601	.488			.159	$\underline{.060}$
Inoculations	.342	.405	.209	.196				
Brush Teeth			.332	.349				
Diet	.201	.354	.306	$\underline{.143}$				
Avoid Germs			.366	$\underline{.144}$			.401	.708
Avoid Chills	.239	$\underline{.108}$	$\underline{.311}$	$\underline{.301}$	$\underline{-.230}$	$\underline{-.013}$		
Religion			.354	.378			.310	.240
OTC Medicine			.437	.254				
Traffic Risk Taking								
Cross Street					.748	.775		
Pedestrian Risks					.778	.823		
Take Chances					.572	.604		
Drive Fast					.675	.614		
Cross at Stop Light					.646	.648		
Risky Hobbies					.589	.585		
Follow Traffic Rules	.360	.325			-.496	-.461		
Use Seat Belt			.328	.369	-.337	-.345	.324	$\underline{.169}$
Substance Use Risk								
Don't Drink							.705	.476
Don't Smoke							.771	.688
Don't Take Chemicals							.682	.800
Avoid Pollution							.595	.605
Drink and Drive					.356	.233	-.375	-.289
Avoid Crime Areas					-.237	$\underline{-.108}$	.493	.552

Note: Underlined parameter estimates were less than twice as large as their estimated standard errors. Blank entries indicate parameters fixed at zero.

covariance matrix resulted in only minor modifications of the factor structure.

The results obtained with the confirmatory sample data could be expected to be similar to those obtained with the exploratory sample, given the findings reported in Table 1 indicating that the model derived from the exploratory sample data cross-validated in the confirmatory sample data. However, there were some potentially important differences. When factor loadings were estimated for the structural model using data from the confirmatory sample, 9 of 58 hypothesized loadings failed to produce parameter estimates that were twice the size of the corresponding standard error estimate. Two of these 9 nonsignificant results were for "Fix broken things" and "Know first aid" on Wellness Behavior, thereby confirming the inappropriateness of assigning these behaviors a weight on Wellness Behavior. Note that both "failures" were instances of secondary loadings for items with multiple factor loadings in the earlier analyses and that the primary factor loading replicated for both items. The 7 remaining hypothesized loadings which were nonsignificant in the confirmatory sample data were: (a) Watch weight on the substance use risk dimension; (b) Avoid chills on the accident control dimension; (c) Avoid chills on the traffic risk taking dimension; (d) Diet on wellness behavior; (e) Avoid exposure to germs on wellness behavior; (f) Use seat belts on substance use risk; and (g) Avoid high crime areas on traffic risk taking. Five of these 7 failures were for secondary loadings, so, overall, 7 of 18 secondary loadings incorporated into the model did not meet the significance criterion, while 38 of 40 primary loadings did. The two primary loadings which failed to meet the significance criterion had small average factor loadings in the earlier analyses ((d) and (e) with loadings of .32 and .36, respectively). If the loadings which were not significant in the confirmatory sample were excluded from the measurement model, only 9 of 40 health behaviors would have loadings on more than one dimension. Thus, a relatively simple, reliable measurement model for health behaviors was obtained.

The possibility that the model had been misspecified by fixing the loading for important behavioral indicators for a given dimension at zero (i.e., that there were false negatives in the measurement model) was considered with an emphasis on the replicability of discrepancies between the hypothesized factor structure and the model in the confirmatory sample. The modification indices for factor loadings fixed at zero in the model were examined to determine which, if any, were large in both groups in the confirmatory sample. There were 102 loadings which were fixed at zero (4 x 40 minus 58), so the probability that at least one large, replicable difference would be found by chance was substantial. To guard against this, the experiment-wide error which would be acceptable was set at 5%, and the nominal significance level for an individual result was set at the Bonferroni level of .00049 (Harris, 1985). Whether a given loading exceeded this significance criterion was determined on the basis of the pooled probability estimate derived by the method of adding probabilities for the two samples with each modification index treated as a chi-square with one degree of freedom. Taking this approach, none of the values which were constrained to be zero met the criterion for statistically significant evidence of misfit between the model and the data.

The preceding findings indicated that the two samples produced comparable results with respect to the general structure of the health behavior measurement model. It should be noted, however, that, cumulatively, the factor loading estimates obtained in the confirmatory sample deviated significantly from those in the exploratory sample. This assertion is based on comparing the chi-square for the 4-factor invariant model obtained for the confirmatory sample data by estimating the model parameter values directly from that data (chi-square = 2400.32) to the chi-square obtained by cross-validating the exploratory sample parameter estimates for the same model by applying them to the confirmatory sample data (chi-square = 2511.66). The difference between these chi-squares was highly significant (chi-square = 111.34, 64 df, $p < .001$), but the observed difference in the value of the fitting function would have been statistically nonsignificant if the sample size had been reduced to 246. Despite the statistical significance of the differences and the relatively small critical N, the parsimony indexes favored the cross- validated model over the sample-specific model, because the absolute improvement in fit was small relative to the number of degrees of freedom used to obtain this improvement.

Considering the two analyses together, 38 of 40 hypothesized primary loadings replicated, 11 of 18 secondary loadings were replicated, and all 102 constrained loadings were replicated. Comparable decisions about the significance of the measurement parameters would be obtained in both samples for 151 of 160 parameter estimates. The elements of the measurement model that were reliably significant across samples and groups provided a relatively simple measurement model in which 31 items had loadings on a single factor and 9 items had loadings on two factors.

Estimated Correlations between Health Behavior Dimensions

The third major issue addressed in this study was the extent of correlation between the health behavior dimensions. The estimated correlations between the latent health behavior dimensions are presented in Table 3 for the 4-factor solutions for both the confirmatory and exploratory samples. Although these estimated correlations differed somewhat from the confirmatory sample to the exploratory sample, on the whole, the differences were small relative to sampling error. In the confirmatory sample, the standard errors for the correlations ranged from .061 to .079. The 95% confidence intervals, therefore, were between .120 and .155. Furthermore, the standard error was largest for the correlation between Wellness Behavior and Substance Risk Taking, so even the observed difference of .138 (absolute) between the confirmatory and exploratory sample estimates for this association would be within the 95% confidence interval for the confirmatory sample estimate.

Table 3
Estimated Correlations between Latent Health Behavior Dimensions

Confirmatory Sample				
Accident Control	1.000			
Wellness Behavior	.525	1.000		
Traffic Risk-Taking	-.241	-.162	1.000	
Substance Risk-Taking	-.532	-.359	.371	1.000
Exploratory Sample				
Accident Control	1.000			
Wellness Behavior	.608	1.000		
Traffic Risk-Taking	-.289	-.158	1.000	
Substance Risk-Taking	-.503	-.493	.408	1.000

NOTE: The correlations reported in this table are the estimated true score correlations for the latent health behavior dimensions represented by the phi matrix in LISREL VI.

A different way of arriving at the same observation regarding the variability of the correlations between dimensions was provided by the modification indices computed by the LISREL VI program. These modification indices represent the minimum change in the model chi-square which would result from freeing a constrained parameter (Joreskog & Sorbom, 1981). When the parameter estimates from the exploratory sample were applied to the confirmatory sample in the replication analyses, modification indices were estimated for each of the correlations between the latent traits. The modification index for the Wellness-Substance Risk Taking correlation was 3.63 in the recruit sample and 1.09 in the shipboard sample. The chi-square for each sample failed to reach the critical value of 3.84 for 1 degree of freedom, and the sum for the two values was less than the critical value of 5.99 for 2 degrees of freedom if they had been summed.

If a .35 (absolute) criterion were established to identify primary health behavior dimensions which were indicators of a common higher-order dimension, the results would conform perfectly to the hierarchical explanatory model proposed on the basis of earlier analyses of the exploratory sample (Vickers, et al., 1988). One higher-order factor would be defined by Wellness, Accident Control, and Substance Risk-Taking and a second higher-order factor would be defined by Traffic Risk-Taking and Substance Risk-Taking. Note, however, that the difference is a matter of degree, as all of the correlations produced t-values greater than 2.23 (absolute), thereby exceeding the value recommended by Joreskog and Sorbom (1981) as the criterion for a significant effect. This trend applied to both the exploratory samples and the confirmatory samples, despite the smaller size of the latter sample.

DISCUSSION

Addressing the last of the three questions posed at the outset of this study first, a single structural model for health behaviors can be applied to samples drawn from different subsets of male Navy personnel. Although the group-specific models typically produced better fits between the model and the data, the improvement in fit was not sufficient to justify the increased theoretical complexity of assuming distinct measurement models. The increment in fit was statistically significant by the chi-square tests, but several other considerations indicated that the group-invariant model was the appropriate choice. First, statistical significance was clearly evident only in the large exploratory sample groups. Second, fit indices adjusted for the degrees of freedom in the models consistently favored the group-invariant model, particularly when the principle of parsimony was applied. Finally, the group-invariant model was supported strongly by the finding that this model cross-validated better than the group-specific model.

Taking the group-invariant model as the appropriate frame-of-reference, it is possible to return to the questions of how many dimensions are required to represent health behaviors and how highly correlated these dimensions are. The present investigation supported the previous inference that four dimensions are required to account for covariation between different health behaviors. In every comparison, the 4-dimensional model produced substantially better fit to the data than the 2-dimensional model. The improvement in fit would have been statistically significant even with very small samples, and the 4-dimensional model consistently was preferable according to parsimony indices.

Considering the issue of correlations between health behavior dimensions, the predicted pattern of correlations was obtained, but the absolute value of these correlations was larger than those for unit-weighted composites as expected. Technical, the shipboard sample was the only independent confirmation of the predicted pattern, as Vickers, et al. (1988) included the present recruit sample as one group used to estimate correlations between unit- weighted behavior composites. The larger size of the correlations was predicted given the present use of structural modeling to obtain estimates of error-free true score correlations, but it also should be noted that the present analyses employed more markers for each dimension and used differential weighting procedures which is another means of increasing the measurement precision of linear composites (Armor, 1974).

The most important point deriving from the consideration of correlations between health behavior dimensions is not that the pattern of correlations is stable across samples. The most important point is that the magnitude of the correlations was too small to suggest that any pair of dimensions was equivalent. Even under the approximation to optimum conditions represented by the present structural equation analysis, none of the correlations approached 1.00 (absolute) in value. In fact, the largest correlation in either sample was just under .61, a value which indicates moderate overlap between different dimensions, but certainly is too small to justify a claim of equivalence between the dimensions. This point must be emphasized, because it is a strong argument in support of the conclusion that it would be inappropriate to combine the health behaviors into assessments of only two dimensions.

One unanticipated trend in the present analyses was the suggestion that the previous conceptualization of one health behavior dimension ought to be reconsidered. The health behaviors defining the dimension previously referred to as "substance use risk" were sufficiently strongly related to other behaviors involving avoidance of exposure to germs, pollution, and so on, to suggest that the conceptualization of this dimension perhaps should be revised to reflect a general tendency to avoid exposing the body to factors which might overtax its adaptive capacities. This revised interpretation is close to a "hazards avoidance" dimension described by Vickers and Hervig (1984). The addition of these markers to the measurement model did not, however, change the pattern of correlations between this dimension and the other health behavior dimensions and did not, therefore, affect the general conceptualization of the structure of health behaviors.

The combined results of this and earlier studies provide a structural equation model for measuring health behaviors. This model can be used as a reference point for confirmatory factor analyses to test specific hypotheses in future research or as a guide to constructing standard scales by combining responses to items dealing with specific behaviors. The value of this achievement may be minimal, however, if recent proposals that health behaviors should not be combined into overall indicators are supported by further research. Slater and Linder (1988) have argued that combining behaviors deletes important information, but this argument should be explored further. The resolution of the issues raised by this argument may depend on making appropriate distinctions between different issues that can be investigated in relation to health behaviors. For example, if one were conducting a prospective study to identify behavioral factors that distinguished individuals who would subsequently develop cirrhosis of the liver from individuals who would subsequently develop lung cancer, and distinguished both of these groups from individuals who would remain free of clinical disease, combining alcohol consumption and smoking into an overall index of substance-use risk-taking or the even broader dimension of avoidance of hazardous substances would be inappropriate. However, if one were interested in factors which gave rise to the tendency to accept or avoid a number of behaviorally-determined health-related risks, a multi-behavior composite could provide more reliable assessment of this general tendency, thereby increasing the effective statistical power of the research for any given sample size. Information about the pattern of associations between health behaviors also can be important in instances where the construction of a multi-behavior composite is not desirable because the effects of a single behavior are the focus of investigation. In this case, information about other behavioral correlates of the target behavior can be used to ensure that measures of correlated behaviors are included in the study. This procedure can help avoid inappropriate interpretations of spurious effects occurring in models which exclude a correlated true cause of an outcome when estimating the effect of the target behavior (cf., James, Mulaik & Brett, 1982). Thus, there are reasons for further consideration of the patterning of behaviors no matter what the final resolution of the issues raised by Slater and Linder (1988) may be, and the present framework provides a useful benchmark for further work in these areas.

Future research should be conducted with an awareness that the sampling of respondents and health-relevant behaviors may have influenced the present findings. The current results indicate substantial factorial stability within samples of male U.S. Navy personnel, but generalization from this population to other populations should be made cautiously. Although there is no reason to believe these young men differ substantially from the corresponding civilian population from which they are drawn, patterns of health behavior may be influenced by a wide range of demographic variables which were beyond the scope of this study. Thus, the appropriateness of the model for the specific population being investigated should be a routine component of any study employing the structural model described here, but apparent differences should be evaluated cautiously in view of the present findings regarding the replicability of sample-specific measurement structures.

The sampling of health-relevant behaviors represents a second possible limitation on the generalizability of the present findings. While the list of behaviors includes many behaviors which are useful indicators of proposed conceptual distinctions (Green, 1984; Langlie, 1979) and which have been mentioned when people are interviewed about perceived health-relevant behaviors (Williams & Wechsler, 1973), the list certainly is not exhaustive. The proposed factor structure, therefore, provides a working model which can be a frame of reference for more detailed studies designed to identify and catalogue a wider range of health-relevant behaviors.

The general conclusion from this study is that the 4-dimensional model of health behaviors described in our prior research provides a viable, replicable structure for assessing differences in health-related behaviors. Ongoing work indicates that the four dimensions of behavior have somewhat distinctive patterns of association to larger behavioral or personality patterns, thereby providing initial evidence of discriminant validity (Booth-Kewley & Vickers, in preparation) and the potential to refine the interpretation of these dimensions. Topics such as the appropriateness of adding behaviors into overall composites, refining the domain and structural definition of health behaviors, and identifying antecedents and consequences of the behavioral patterns can be considered in future research using this framework as a starting point.

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Appendix A

Health Behavior Items and the Structural Models

	Dimension*: 1 2	1 2 3 4
Wellness Behaviors		
I exercise to stay healthy.	1 0	0 1 0 1
I gather information on things that affect my health.	1 0	0 1 0 0
I see a doctor for regular checkups.	1 0	1 1 0 0
I see a dentist for regular checkups.	1 0	0 1 0 0
I discuss health with friends, neighbors, and relatives.	1 0	0 1 0 0
I limit my intake of foods like coffee, sugar, fats, etc.	1 0	0 1 0 1
I use dental floss regularly.	1 0	0 1 0 0
I watch my weight.	1 0	0 1 0 1
I take vitamins.	1 0	0 1 0 0
I eat a balanced diet.	1 0	1 1 0 0
I take health food supplements (e.g., protein additives).	1 0	0 1 0 0
I stay away from places where I might be exposed to germs.	1 1	0 1 0 0
I avoid areas with high pollution.	1 0	0 0 0 1
I get shots to prevent illness.	1 0	1 1 0 0
I brush my teeth regularly.	1 0	0 1 0 0
I avoid over-the-counter medicines.	1 0	0 1 0 0
I pray or live by principles of religion.	1 1	0 1 0 1
Accident Control Behaviors		
I keep emergency phone numbers near the phone.	1 1	1 0 0 0
I destroy old or unused medicines.	1 0	1 0 0 0
I have a first aid kit in my home.	1 0	1 0 0 0
I check the condition of electrical appliances, etc., to avoid accidents.	1 1	1 1 0 0
I fix broken things around my home right away.	1 0	1 1 0 0
I learn first aid techniques.	1 0	1 1 0 0
I watch for possible signs of major health problems (e.g., cancer, hypertension, heart disease).	1 1	1 0 0 0
I choose my spare time activities to help me relax.	1 0	1 0 0 0

Health Behavior Items and the Structural Models
(continued)

Dimension:	1 2	1 2 3 4
Traffic-Related Risk-Taking		
I cross busy streets in the middle of the block.	0 1	0 0 1 0
I take more chances doing things than the average person.	0 1	0 0 1 0
I speed while driving.	0 1	0 0 1 0
I take chances when crossing the street.	0 1	0 0 1 0
I carefully obey traffic rules so I won't have accidents.	1 1	1 0 1 0
I cross the street against the stop light.	0 1	0 0 1 0
I engage in activities or hobbies where accidents are possible (e.g., motorcycle riding, skiing).	0 1	0 0 1 0
Substance-Use Risk-Taking		
I do not drink.	0 1	0 0 0 1
I don't smoke.	0 0	0 0 0 1
I don't take chemical substances which might injure my health (e.g., food additives, drugs, stimulants).	1 1	0 0 0 1
I drive after drinking.	0 1	0 0 1 1
I avoid high crime areas.	0 1	0 0 1 1
Miscellaneous		
I get enough sleep.	1 0	1 0 0 0
I wear a seat belt when in a car.	1 1	0 1 1 1
I avoid getting chilled.	1 1	1 1 1 0

*NOTE: The first pair of dimensions indicates loadings for the 2-factor representation of health behaviors; the remaining 4 dimensions refer to the 4-factor representation. The column entry for a given item on a given factor is "1" if a factor loading was estimated for that item on that factor and "0" if not.

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An hierarchical model of health behaviors proposed in earlier studies was evaluated by confirmatory factor analysis. A four-dimensional measurement model was appropriate for both recruit and shipboard Navy men. A structural equation model was provided which is suitable for measuring health behaviors in research on the causes and effects of differences in health behavior.

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